

THE SURVIVAL OF METEORITE ORGANIC COMPOUNDS WITH INCREASING IMPACT PRESSURE

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Introduction

The majority of carbonaceous meteorites studied today are thought to originate in the asteroid belt. Impacts among asteroidal objects generate heat and pressure that may have altered or destroyed pre-existing organic matter in both targets and projectiles to a greater or lesser degree depending upon impact velocities. Very little is known about the shock related chemical evolution of organic matter relevant to this stage of the cosmic history of biogenic elements and compounds. The present work continues our study of the effects of shock impacts on selected classes of organic compounds utilizing laboratory shock facilities. Our approach was to subject mixtures of organic compounds, embedded in a matrix of the Murchison meteorite, to a simulated hypervelocity impact [1]. The molecular compositions of products were then analyzed to determine the degree of survival of the original compounds. Insofar as results associated with velocities <8 km/sec may be relevant to impacts on planetary surfaces (e.g., oblique impacts, impacts on small outer planet satellites) or grain-grain collisions in the interstellar medium, then our experiments will be applicable to these environments as well.

Materials and Methods

Four classes of organic compounds, known to be indigenous to carbonaceous meteorites [2], were chosen for study: Organic sulfur, organic phosphorus, polyaromatic hydrocarbons (PAHs), and amino acids. The organic sulfur compounds are methane sulfonic acid (MSA), ethane sulfonic acid (ESA), n-propane sulfonic acid (nPSA), and iso-propane sulfonic acid (iPSA). The organic phosphorous compounds are methyl phosphonic acid (MPA), ethyl phosphonic acid (EPA), and tert-butyl phosphonic acid (tBPA). The PAHs are 2-methylanthracene, 2-tert-butyl anthracene, dibenzothiophene (deuterated), acridine (deuterated) 1-pyrenebutyric acid, and coronene. The amino acids: L-glutamic acid, alpha-amino isobutyric acid, and glycyl glycine (a peptide).

The deuterated PAHs were chosen to represent meteoritic counterparts while removing the ambiguities associated with the problem of contamination during sample handling and analysis. They also can be distinguish from ordinary PAHs that may be released by impact from the insoluble macromolecular organic matter in meteoritic mineral matrices. Sulfonic and phosphonic acids were chosen in part because they occur in Murchison, they are relatively stable compared to other classes of polar organic compounds, and they are the only well-characterized classes of homologous organic sulfur and phosphorous containing compounds identified in extraterrestrial materials.

A known amount of each compound was added to a sample of powdered Murchison meteorite. Water was then added to the mixture followed by vortexing (to thoroughly mix), and drying by rotary evaporation. The sample was then further dried over sodium hydroxide overnight. Portions of the mixture were then removed, placed in a projectile and sealed airtight (with a metal screw) and were therefore devoid of any interior contamination generated by the firing process. The shock experiment was done in the Experimental Impact Laboratory of the Johnson Space Center, Houston and is more fully discussed in [3]. A 20 mm gun, with its barrel extending into a vacuum chamber (10⁻² torr), was used to launch the projectile containing the sample at ~1.6 km/sec into various target material. These materials resulted in the samples experiencing various pressures in the range of 100-400 kb (pressure translates into impact velocity). Approximate pressures were 100, 200, 300, and 400kb. After impact, the samples were extracted with water or organic solvents and analyzed by a combination of ion chromatography, HPLC, and gas chromatography-mass spectrometry.

Results

Analysis of the data shows generally that survival of the compounds studied is inversely proportional to shock pressure. However at lower pressures, 100-200 kb, the sulfonic acids show nearly complete survival. There was a significant drop in survival at approximately 300 kb of pressure for all organic sulfur and phosphorous compounds. Pressures of 300-400kb resulted in survivals of approximately 20-30% for one and two carbon compounds (MSA, MPA, ESA), while the three and four carbon compounds (nPSA, iPSA, and tBPA) survived at rates of approximately 0-10%. A replicate experiment yielded the same general trend. For the PAHs, a similar trend was observed as the fraction of surviving compounds decreased with increasing shock pressures. More detailed analysis of survival rates of individual compounds, isotope exchange in PAHs, and chemical synthesis due to impact will be presented.

These preliminary results indicate that significant amounts of sulfonic and phosphonic acids and PAHs would have survived impacts within the asteroid belt throughout solar system history. Compounds of these types found in meteoritic samples were probably formed directly (or from precursors) on the parent bodies or accreted within asteroids from an earlier epoch of interstellar organic synthesis. Impact synthesis of these meteoritic organics on the parent bodies appears unlikely. In the context of asteroidal impacts on Earth, the results also suggest that organic compounds would have survived in objects that experienced impact shocks at or below 300-400 kb.

References:

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